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SATELLITE DOMAIN ANALYSIS REPORT FOR REUSABLE SOFTWARE ARCHITECTURE FOR SPACECRAFT

Amy Flanagan
Benjamin Moultrie

Martin Marietta Technologies, Inc.
Astronautics
P.O. Box 179
Denver, CO 80201-0179

December 1995

Final Report

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PHILLIPS LABORATORY
Space and Missiles Technology Directorate
AIR FORCE MATERIEL COMMAND
KIRTLAND AIR FORCE BASE, NM 87117-5776

PL-TR--95- 1007

This final report was prepared by Martin Marietta Technologies, Inc. Denver, CO, under Contract F29601-94-C-0114 Phillips Laboratory, Kirtland Air Force Base, New Mexico, under Job Order 2181TBBA. The Laboratory Project Officer-in-Charge was Ross Wainwright (VTQ)

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Ross H Wainwright

ROSS H. WAINWRIGHT
Project Officer

FOR THE COMMANDER

Christine M Anderson

CHRISTINE M. ANDERSON, GM-15
Chief, Satellite Control and Simulation Division

Henry L Pugh Jr

HENRY L. PUGH, JR., Col, USAF
Director of Space and Missiles Technology

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DRAFT SF 298

1. Report Date (dd-mm-yy) December 1995	2. Report Type Final	3. Dates covered (from... to) 01/95 to 12/95

4. Title & subtitle Satellite Domain Analysis Report for Reusable Software Architecture for Spacecraft	5a. Contract or Grant # F29601-94-C-0114
	5b. Program Element # 78026F
6. Author(s) Amy Flanagan Benjamin Moultrie	5c. Project # 2181
	5d. Task # TB
	5e. Work Unit # BA

7. Performing Organization Name & Address Martin Marietta Technologies, Inc. Astronautics P. O. Box 179 Denver, CO 80201-0179	8. Performing Organization Report #
9. Sponsoring/Monitoring Agency Name & Address Phillips Laboratory 3550 Aberdeen Ave SE Kirtland AFB, NM 87117-5776	10. Monitor Acronym
	11. Monitor Report # PL-TR-95-1007

12. Distribution/Availability Statement
Approved for public release; Distribution is unlimited.

13. Supplementary Notes

14. Abstract The Reusable Software Architecture for Spacecraft (RSAS) project has as an objective, the development of an engineering "Workbench" which will partially automate the production of flight software. The Workbench will house a generic flight software domain architecture which will be tailorable to mission specific requirements. Guided by the tailored domain architecture, the Workbench will assemble reusable flight software components to synthesize a mission flight application. This report provides an overview of the satellite flight system domain analysis performed in support of the development of reusable flight software components. Eight diverse flight systems were surveyed and analyzed to identify common functional attributes and requirements. The Shlaer-Mellor Object-Oriented Analysis methodology was used to guide the domain analysis and the development of domain models. A generic flight system domain architecture was developed to capture the functional commonalities identified in the survey.

15. Subject Terms flight software, Shlaer-Mellor Object-Oriented Analysis, flight system domain

Security Classification of			19. Limitation of Abstract	20. # of Pages	21. Responsible Person (Name and Telephone #)
16. Report unclassified	17. Abstract unclassified	18. This Page unclassified	Unlimited	64	Ross Wainwright (505) 846-0461 x 319

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Reusable Software Architecture for Spacecraft (RSAS) project has as an objective the development of an engineering "Workbench" which will partially automate the production of flight software. The Workbench will house a generic flight software domain architecture which will be tailorable to mission specific requirements. Guided by the tailored domain architecture, the Workbench will assemble reusable flight software components to synthesize a mission flight application. This report provides an overview of the satellite flight system domain analysis performed in support of the development of reusable flight software components.

Eight diverse flight systems were surveyed and analyzed to identify common functional attributes and requirements. The Shlaer-Mellor Object-Oriented Analysis methodology was used to guide the domain analysis and the development of domain models. A generic flight system domain architecture was developed to capture the functional commonalities identified in the surveyed.

Flight system and subsystem models were constructed to capture information, and data flows and control flows. Lower level models were developed for three satellite subsystems: Guidance, Navigation and Control; Communications; Electrical Power. Subsystem software functions were modeled as components (i.e., "objects") in Information Models. In addition, criteria were defined to prioritize the implementation of software components.

DOMAIN ANALYSIS METHODOLOGY

A survey was conducted to gather requirements from eight independent past, present, or proposed flight projects spanning defense, civil, and commercial systems. The survey included an examination of current academic approaches to flight system specification and design and numerous discussions with subsystem experts. The resulting flight subsystem requirements were captured in a Functional Requirements Matrix (FRM).

Two primary criteria were employed in the selection of projects for inclusion in the survey. First, the characteristics of the selected project had to expand the scope of orbit types, mission types, and types of customers in the survey. Second, experts had to be available to support the definition of satellite requirements for the selected project.

The diversity of projects surveyed provides a comprehensive view of common flight system requirements. The eight flight systems included in the survey are identified in the following table:

Flight Systems Surveyed

Program Name	Customer	Market Sector	Orbit Type	Mission Description	Mission Status
Magellan	NASA-JPL	Civil	Interplanetary/ Low Altitude	Scientific	Operational
Brilliant Pebbles	SDIO	Defense	Classified	Missile Defense	Under Development
Lunar Resource Mapper	NASA-JPL	Civil	Interplanetary/ Low Altitude	Scientific	Awarded, Funding Cut
MSLS	DoD, NASA	Defense, Civil	Booster	Launch Services	Under Development
Earth Observation System	NASA-Goddard	Civil	Low Earth Orbit	Remote Sensing /Earth Science	Proposed
Centaur	DoD, NASA	Defense, Civil	Geosynchronous, Interplanetary	Launch Services	Operational
Brilliant Eyes	SDIO	Defense	Classified	Remote Sensing	Proposed
P-81	Classified	Defense	Classified	Classified	Under Development

DOMAIN ARCHITECTURE

The conceptual context for the Generic Domain Architecture (GDA) for a satellite flight system is shown in the Domain Chart in Appendix A. The Domain Chart displays the satellite domain and its client-server relationships.

The satellite GDA comprises a Subsystem Relation Model (SRM), Subsystem Communications Model (SCM), Subsystem Access Model—and for each subsystem—an Information Model (IM), Object Communication Model (OCM), and Object Access Model (OAM). The SRM defines relationships between subsystems. The SCM and SAM define the control flow and data flow, respectively, between subsystems. The IM defines the relationships between the constituent objects (i.e., components) within a subsystem. The OCM and OAM defines the control and data flows, respectively, between objects within a subsystem. Each model is expressed graphically in the form of a diagram. For convenience, the interface information intrinsic to the SCM and SAM has been captured in textual descriptions on the SRM, thus, effectively combining the SRM, SCM and SAM into a single diagram. Similarly, convenience has motivated a consolidation of the OCM and OAM for each subsystem.

The typical satellite system consists of eight subsystems: Guidance, Navigation and Control (GN&C); Communications (COMM); Command and Data Handling; Electrical Power (EPS); Thermal; Structures and Mechanisms; Propulsion; Payload. Appendix B shows the augmented SRM for the generic satellite system.

GN&C has been divided into four partitions, Attitude Determination (AD), Attitude Control (AC), Orbit Determination (OD) and Orbit Control (OC). Current and foreseeable space mission designs allocate the OC partition the ground system; therefore, the Orbit Control partition of GN&C will not be developed or addressed beyond its representation in the SRM. Information Models have been completed for AC, AD and OD and related OCMs/OAMs will be completed in the near future; corresponding models are under development for COMM and EPS. Information Models for AC, AD and OD are displayed in Appendices C–E, respectively. Each IM is displayed twice, first in full view to provide insight into the corresponding GN&C partition's complexity, and secondly as four mosaic frames to enhance readability.

COMPONENT DOCUMENTATION

The RSAS Software Development Plan (SDP), Martin Marietta document MCR–94–516, prescribes the discipline which is applicable to the documentation of satellite domain reuse components. Components are documented using the Shlaer/Mellor methodology—as implemented in the CASE tool Cadre Teamwork—and in Software Product Development Folders (SPDF). At a future date, components will be documented in detail in a Software Description Document.

Cadre Teamwork provides a vehicle for developing and maintaining satellite domain models, and has capability which supports model syntax and consistency checking. In addition, model information can be captured in graphical and textual formats. Five examples of available Cadre Teamwork managed information formats are provided in Appendix F. The given examples are for a Data Dictionary Entry (DDE), a Data Flow Diagram (DFD), a Process Specification (P-Spec), a State Transition Diagram (STD), and a State Transition Table (STT), respectively. It should be noted that the DDE can be tailored to user needs with the automatic inclusion of selected data, and the P-Spec automatically captures the input/output information at a step in the DFD.

A SPDF is created for each component. It serves as a repository for the component's requirements, design description, source code listing, test description and data, pertinent notes, and other information related to the component's life-cycle. The outline for a SPDF is provided in Appendix G.

IDENTIFIED COMPONENTS

Information Models have been completed for the GN&C partitions. The components for the GN&C partitions are listed in Appendix H. Preliminary lists of components for COMM and EPS are provided in Appendices I and J, respectively.

COMPONENT VERIFICATION

Seven verification criteria have been defined for the purpose of prioritizing the development of components. These criteria are intended to give highest priority to those components which are will be employed earliest or are applicable to multiple mission types. The criteria are as follows:

Criterion Code	Criterion Description
A	The component is legacy (i.e., exists) and conforms to the GDA.
B	The component is applicable to existing flight projects.
C	The component is applicable to proposed flight systems.
D	The component supports existing flight system technologies.
E	The component supports new flight system technology.
F	The component is computer independent.
G	The component's redevelopment costs are high.

To evaluate components, each criterion is assigned an integer "assessment value" from two (2) to zero (0) where lower values reflect lower priority. The assessment values for a component are summed to obtain the priority for that component. Assessment values are defined as follows:

Assessment Value	Interpretation
2	Highly applicable to the component.
1	Somewhat applicable to the component.
0	Not applicable to the component.

The component evaluation tables for the GN&C partitions are provided in Appendix K. A priority has been assigned to each component on the basis of the noted verification criteria. The highest priority possible is fourteen (14). Component evaluation tables will be developed for COMM and EPS when the associated IMs are completed.

SUMMARY

A satellite domain analysis has been completed and a Generic Domain Architecture will be completed in the near future for satellite flight systems. Flight software components have been identified for three subsystems, GN&C, COMM, and EPS. Components are documented using a CASE tool and the discipline prescribed in the RSAS SDP. Component verification criteria have been defined to support the prioritizing of components for development purposes.

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Wertz, J.R., and Larson, W.J., et al., *Spacecraft Mission Analysis and Design,* Kluwer Academic Publishers, ISBN 0 7923 0971 5.

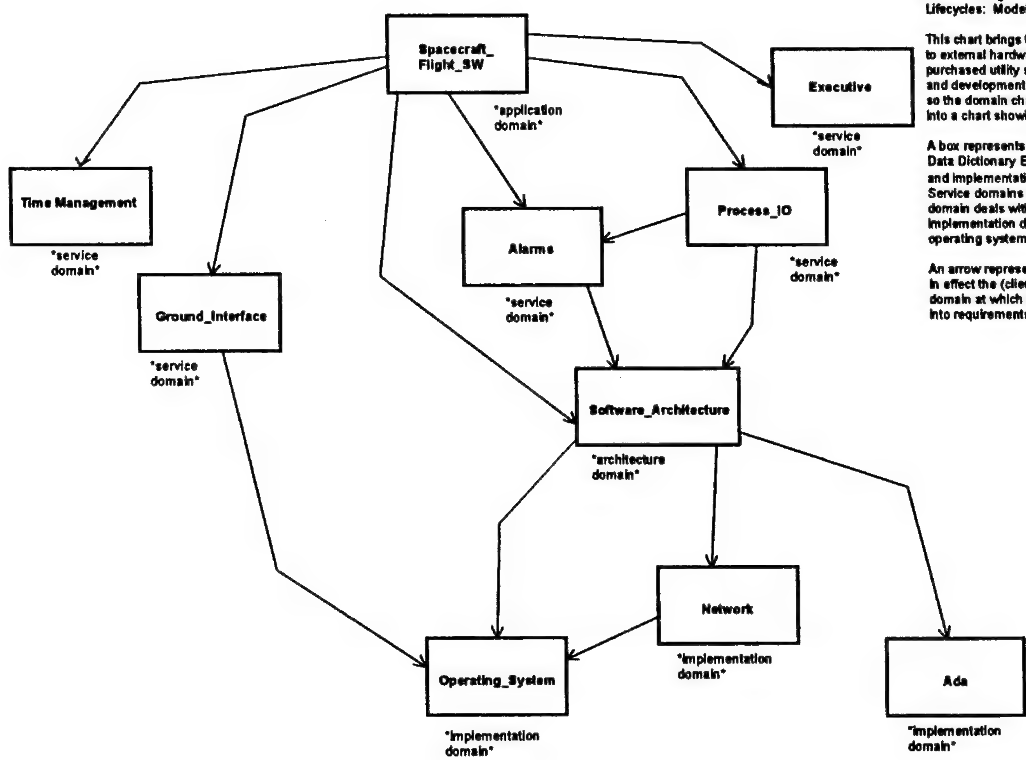
Fortescue, P.W., and Stark, J.P.W., et al., *Spacecraft Systems Engineering,* John Wiley and Sons, ISBN 0 471 92794 5.

Griffin, M.D., and French, J.R., *Space Vehicle Design,* AIAA Education Series, ISBN 0–930403–90–8.

Software Development Plan for the Reusable Software Architecture for Spacecraft, Martin Marietta Astronautics MCR–94–516.

Shlaer, S., and Mellor, S.J., *Object-Oriented Systems Analysis, Modeling the World in Data,* Yourdon Press, ISBN 0–13–629023–X.

APPENDIX A—Satellite Software System Domain Chart



This is a graphical representation of the different domains within reusuable flight software. A generic description of domains can be found in Chapter 7 of "Object Lifecycles: Modeling the World in States" by Sally Shlaer and Stephen Mellor.

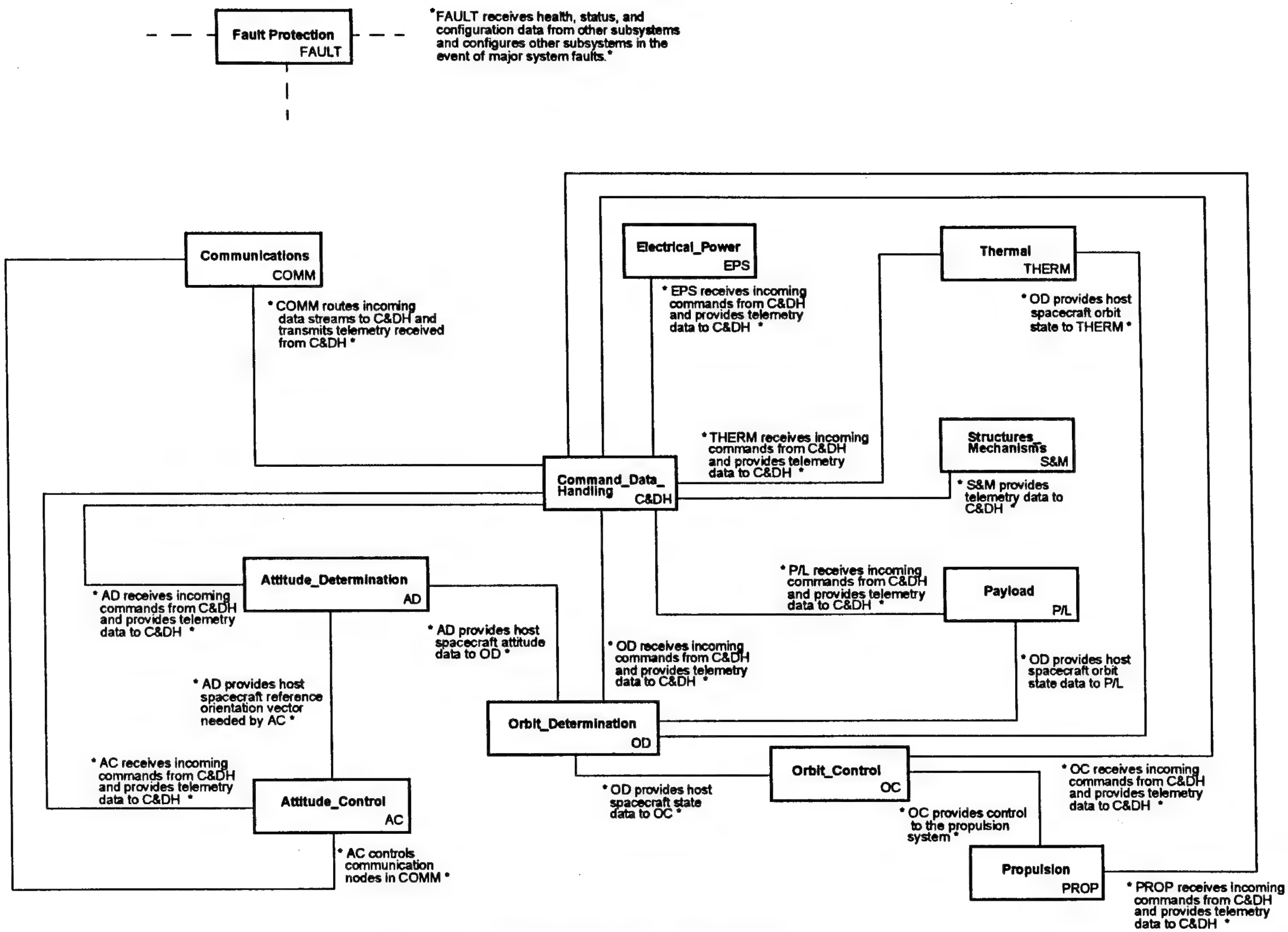
This chart brings together all aspects of a project: the application proper, the interface to external hardware, the user interface, data management services of various sorts, purchased utility software, and finally the operating system, programming languages, and development environment. This is clearly too much material to deal with as a whole so the domain chart packetizes this information into domains and organizes the domains into a chart showing the interrelatedness.

A box represents a domain, its mission statement can be viewed by showing the box's Data Dictionary Entry. A domain comes in one of four flavors: application, service, architectural, and implementation. Application domains are those that we see as constituting the "project". Service domains are common utilities that the application requires. The architectural domain deals with broad, project wide issues like the storing of data in databases. And implementation domains deal with programming languages, development environments, operating systems, and shared libraries.

An arrow represents a bridge which defines a client-server relationship between domains. In effect the (client) domain originating the arrow is making assumptions about the (server) domain at which the arrowhead points. The assumptions held by the "clients" translate into requirements levied on the "server".

Spacecraft System Domain Chart

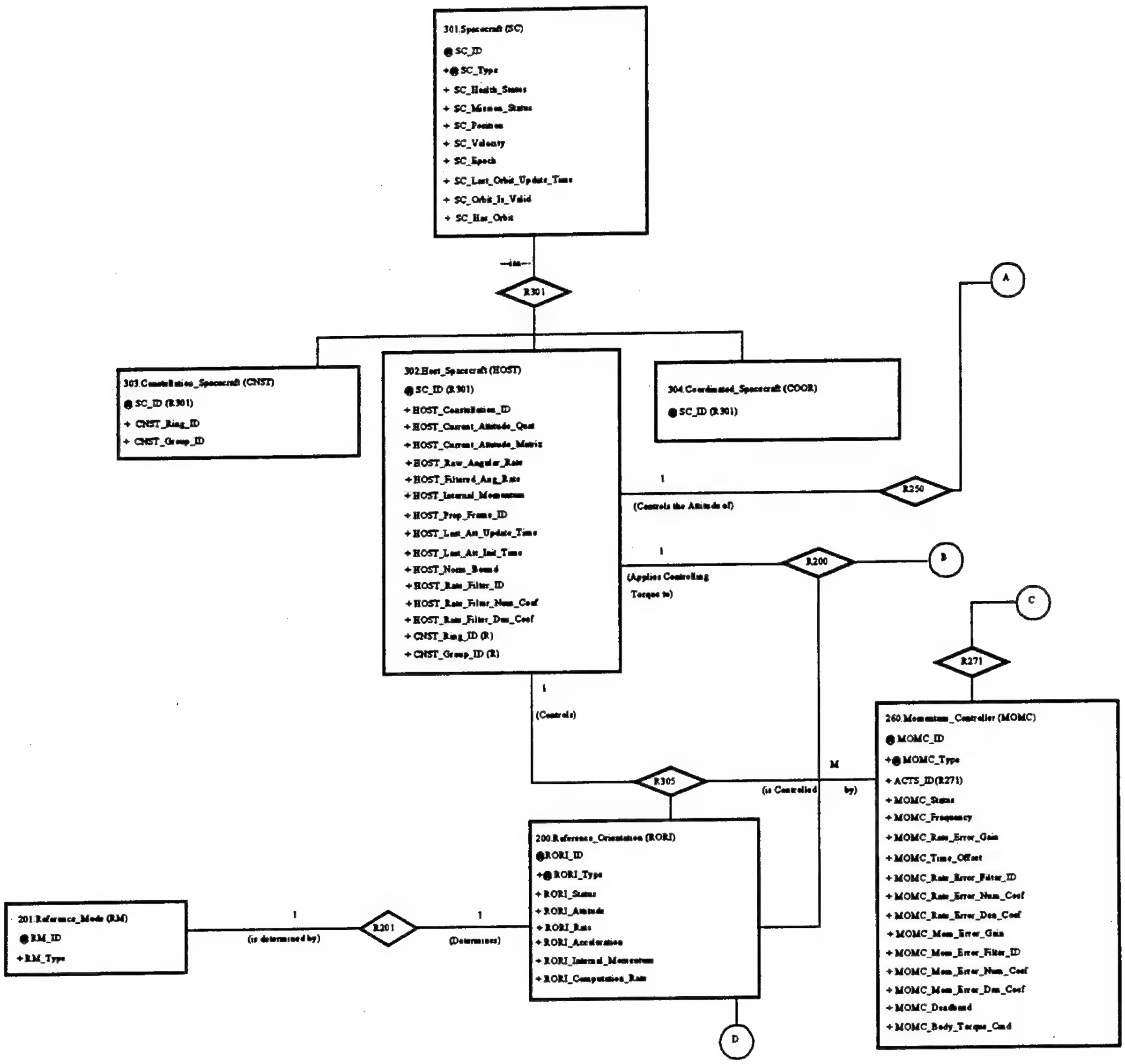
APPENDIX B—Subsystem Relation Model



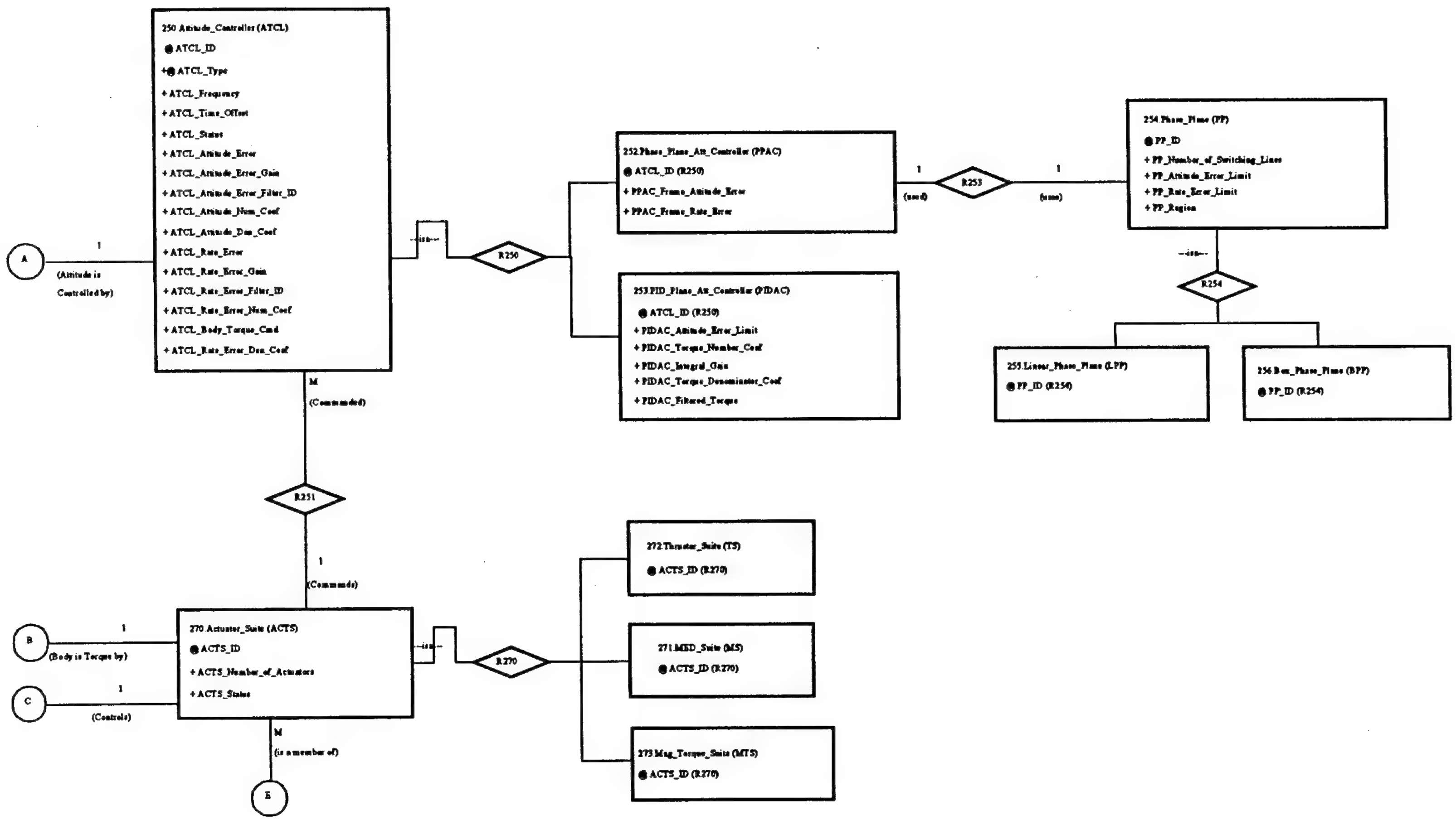
Note: The Attitude_Determination, Orbit_Determination, Attitude_Control, and Orbit_Control partitions collectively comprise the Guidance, Navigation and Control Subsystem.

Subsystem Relationship Model

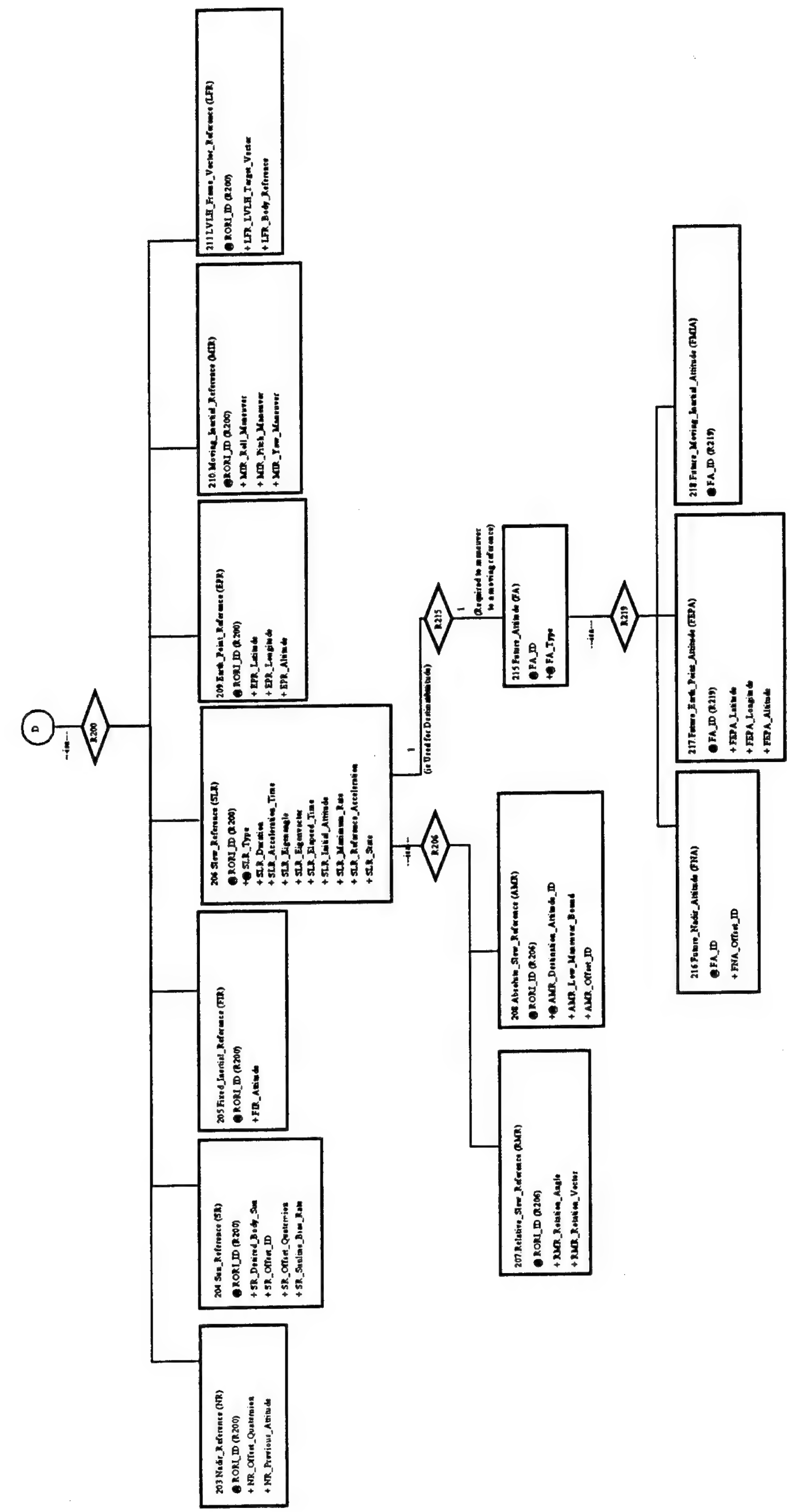
APPENDIX C—Information Model for Attitude Control Partition



Attitude Control Information Model



Attitude Control Information Model (cont'd)



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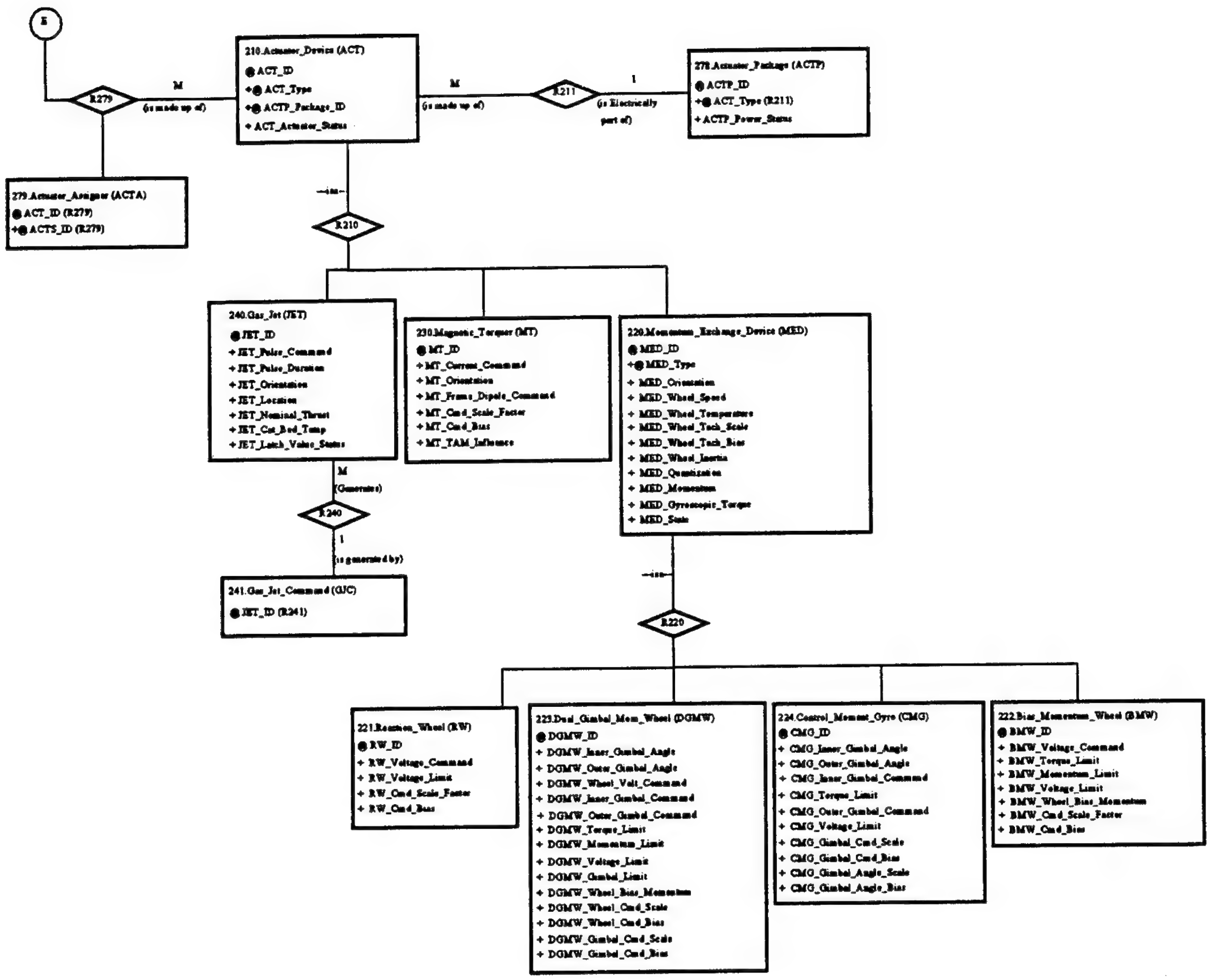
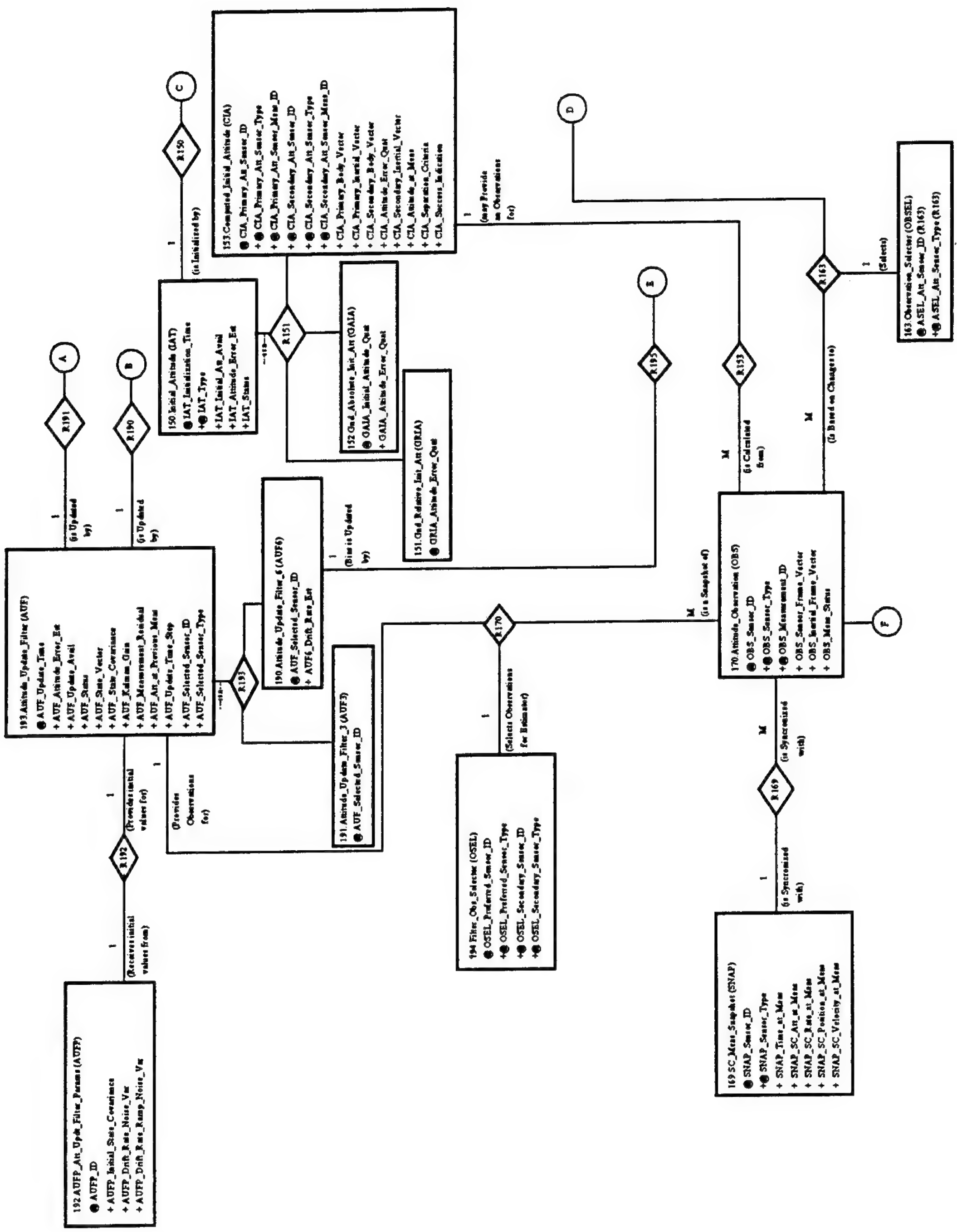
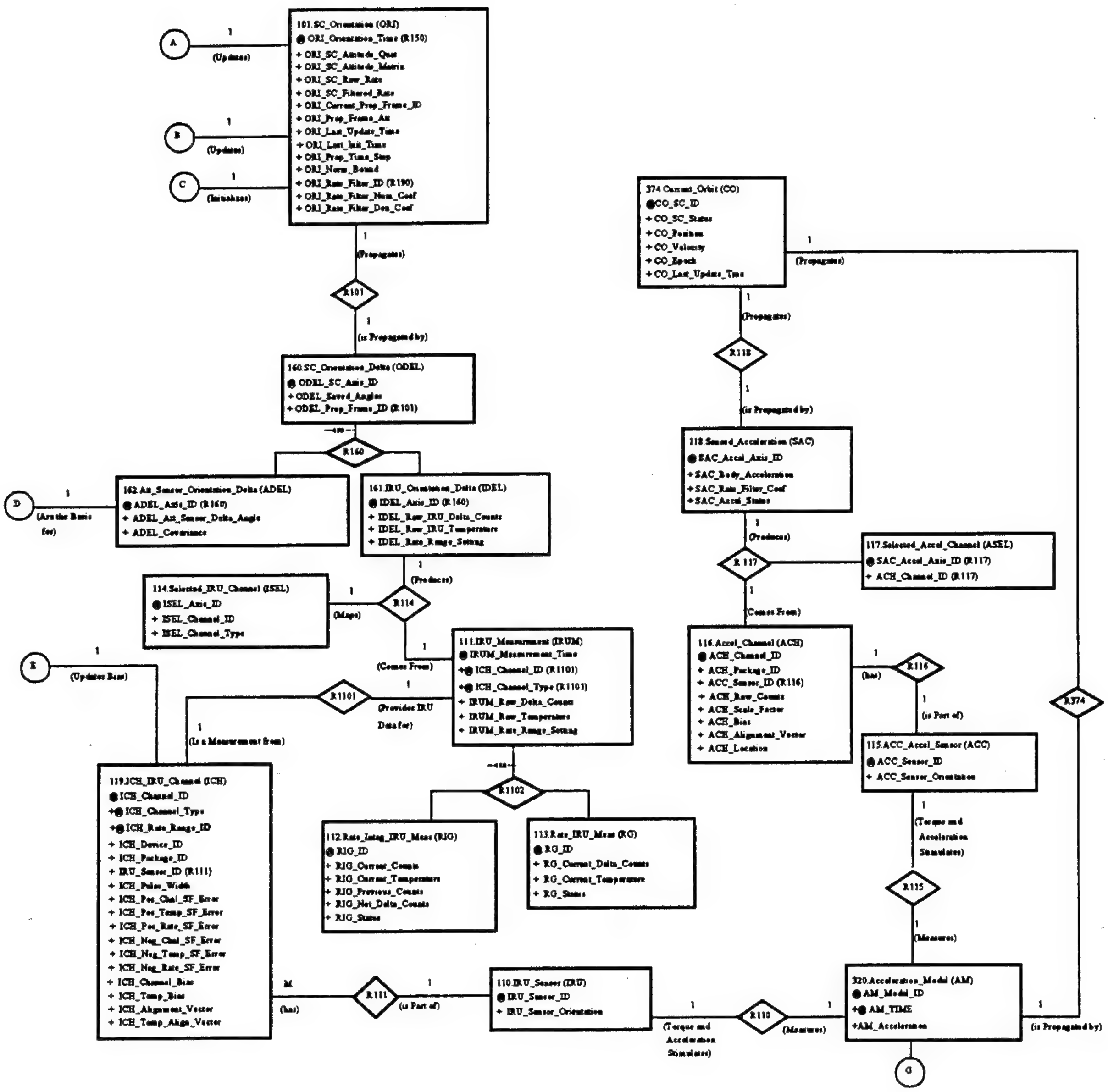


Attitude Control Information Model (cont'd)

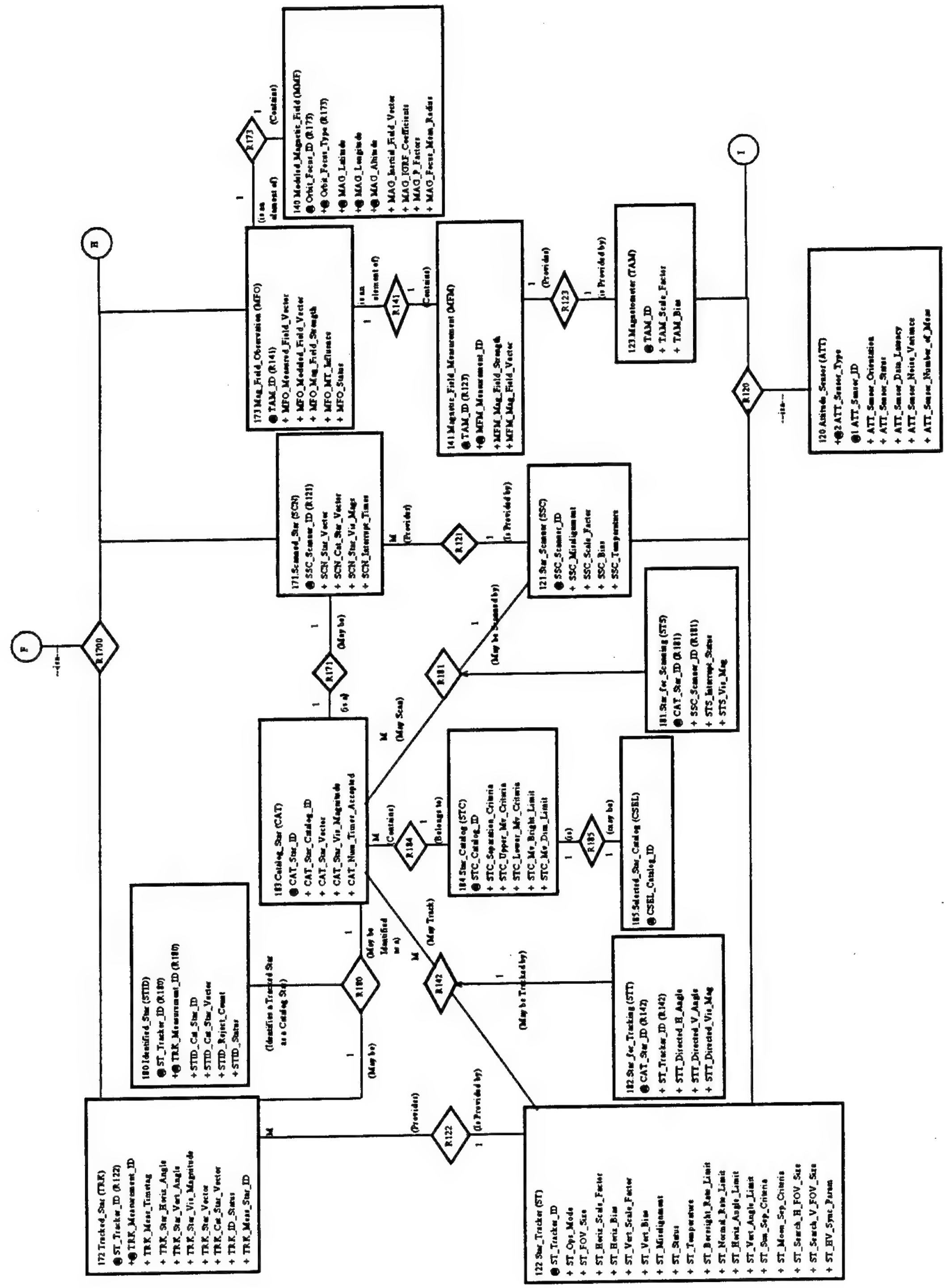
APPENDIX D—Information Model for Attitude Determination Partition



Attitude Determination Information Model



Attitude Determination Information Model (cont'd)



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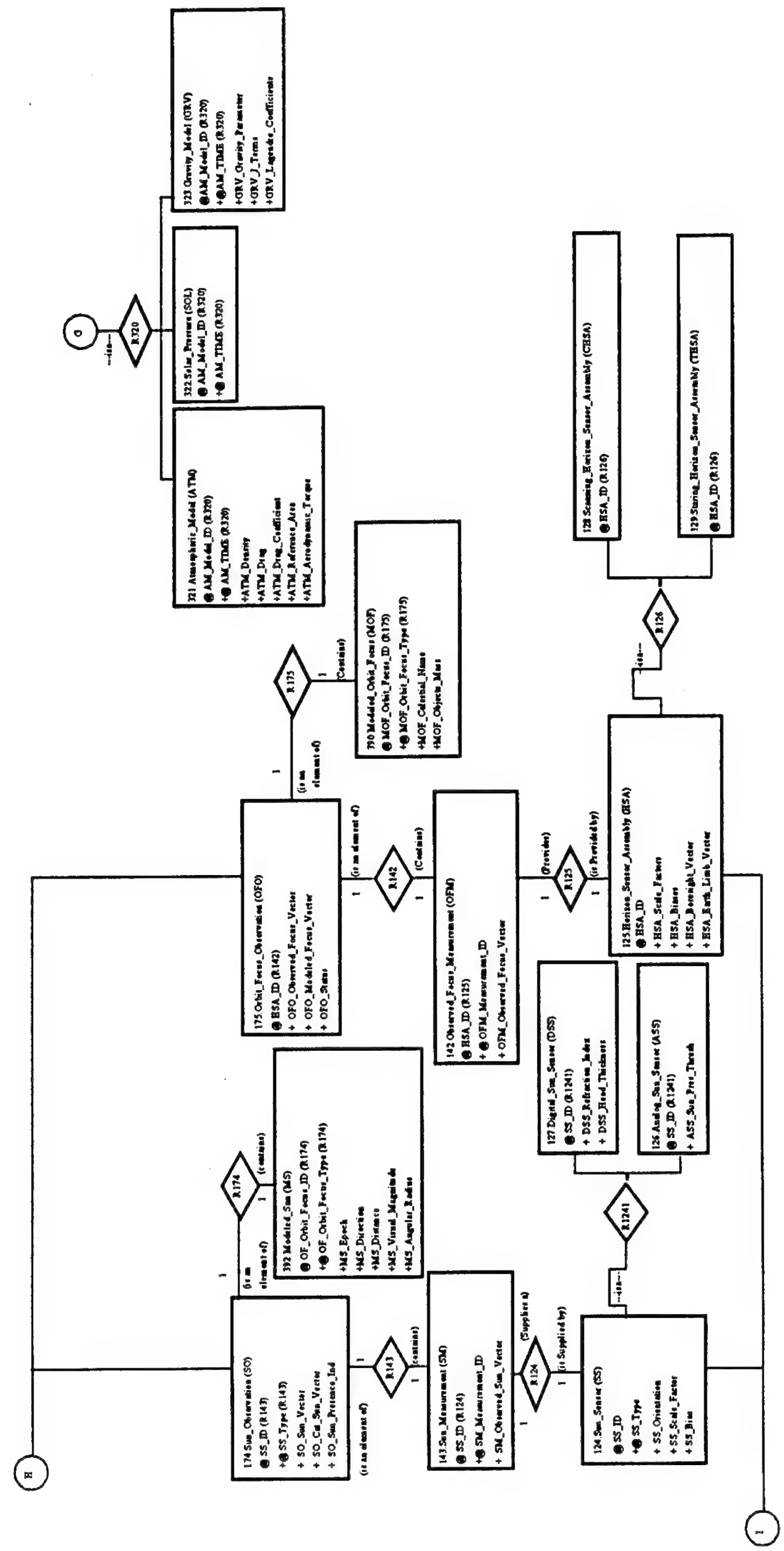
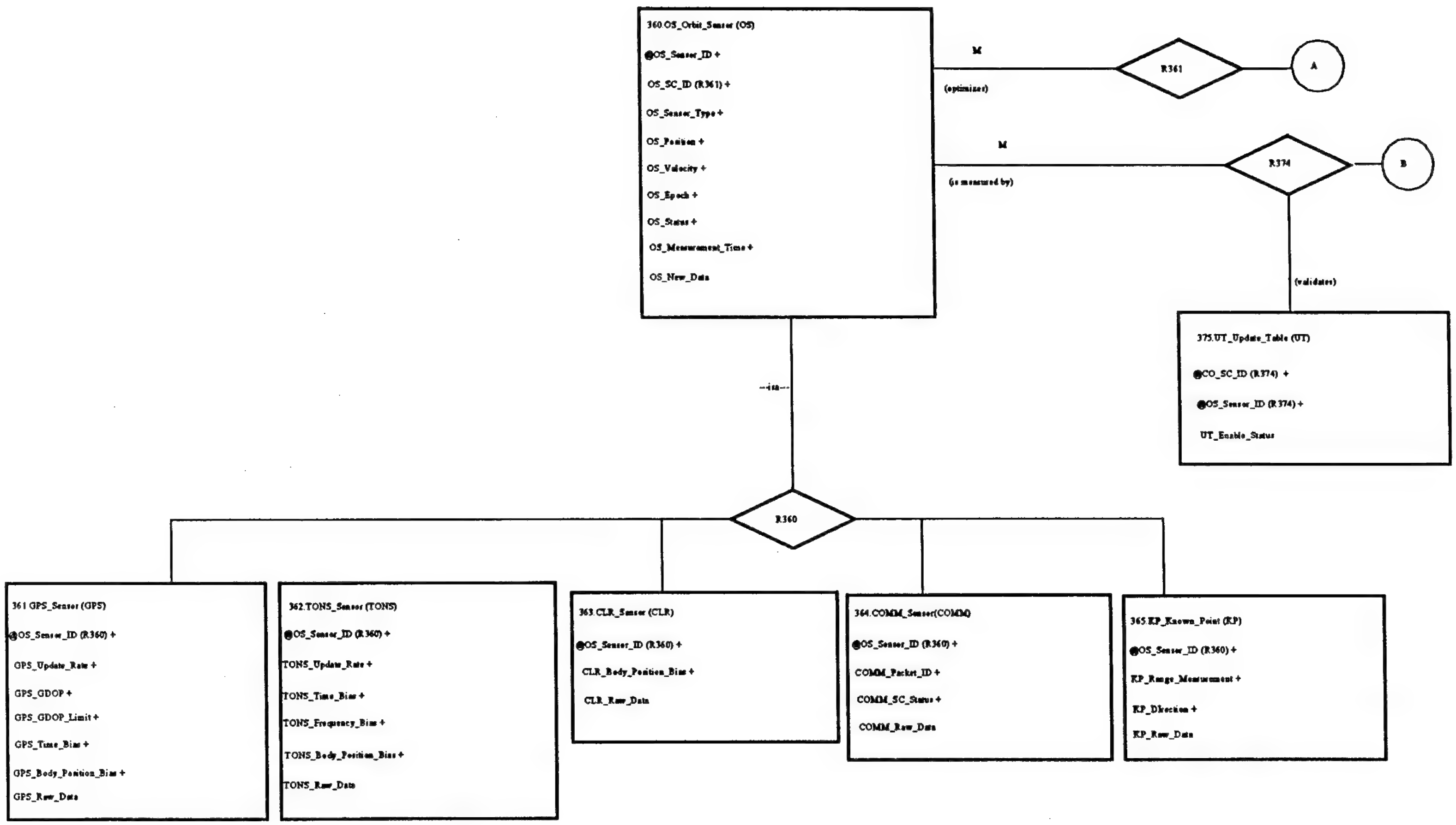
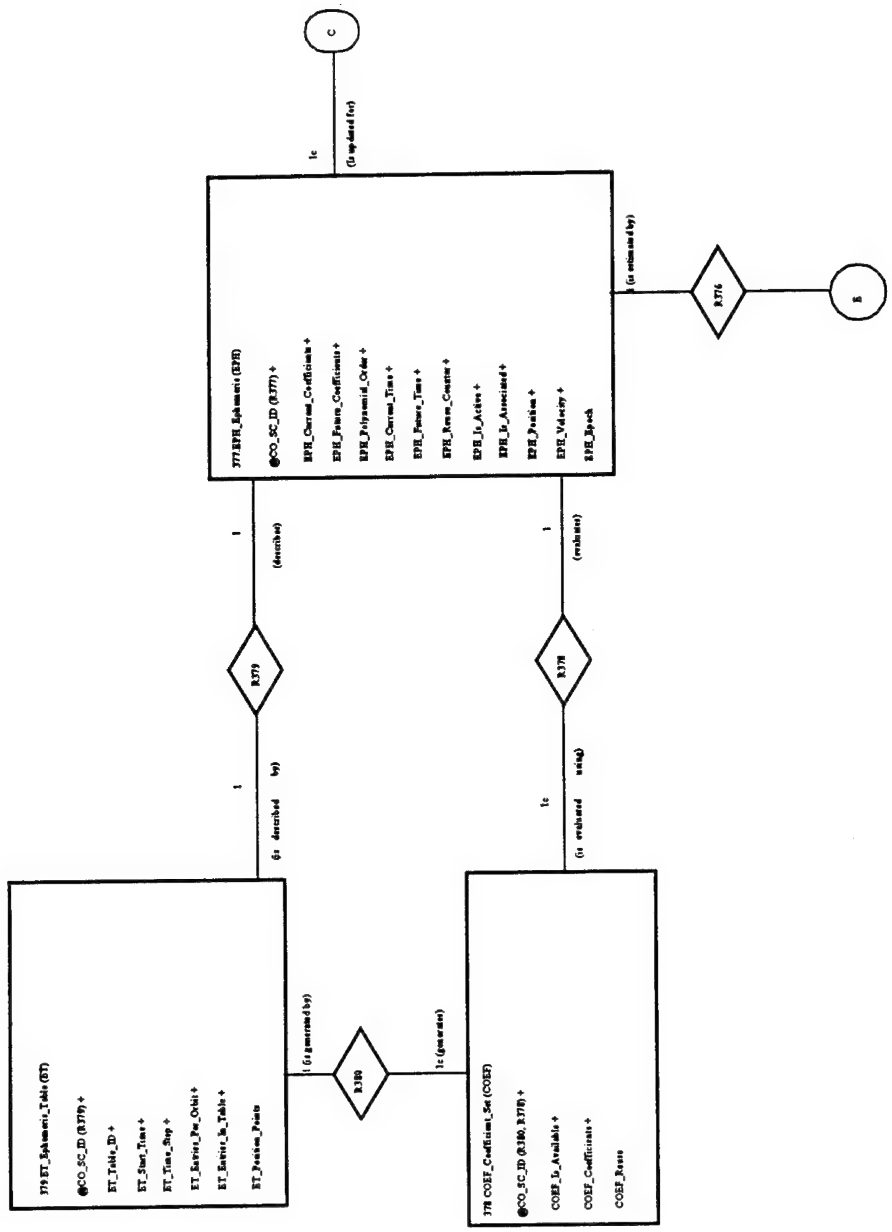


Attitude Determination Information Model (cont'd)

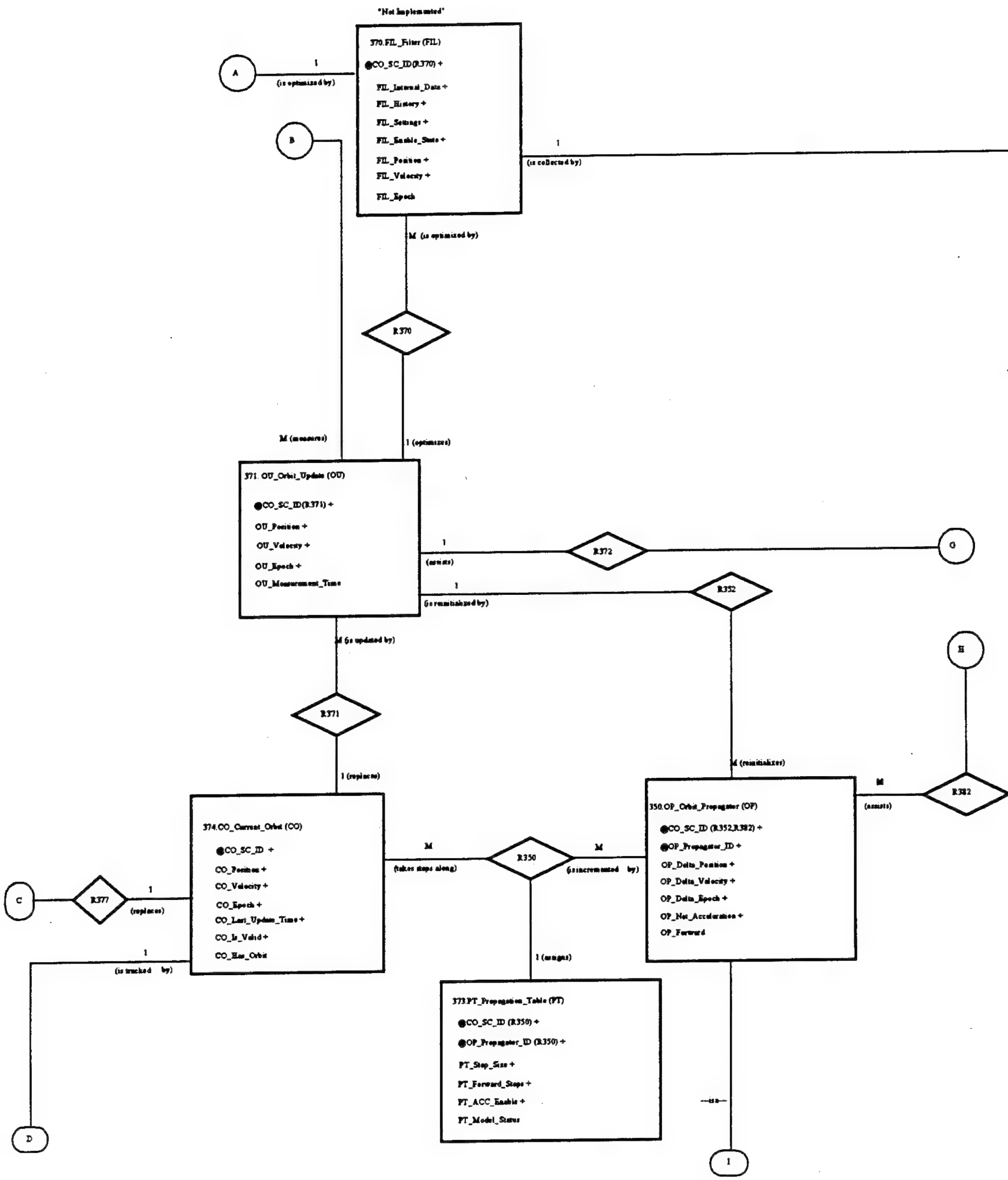
APPENDIX E—Information Model for Orbit Determination Partition



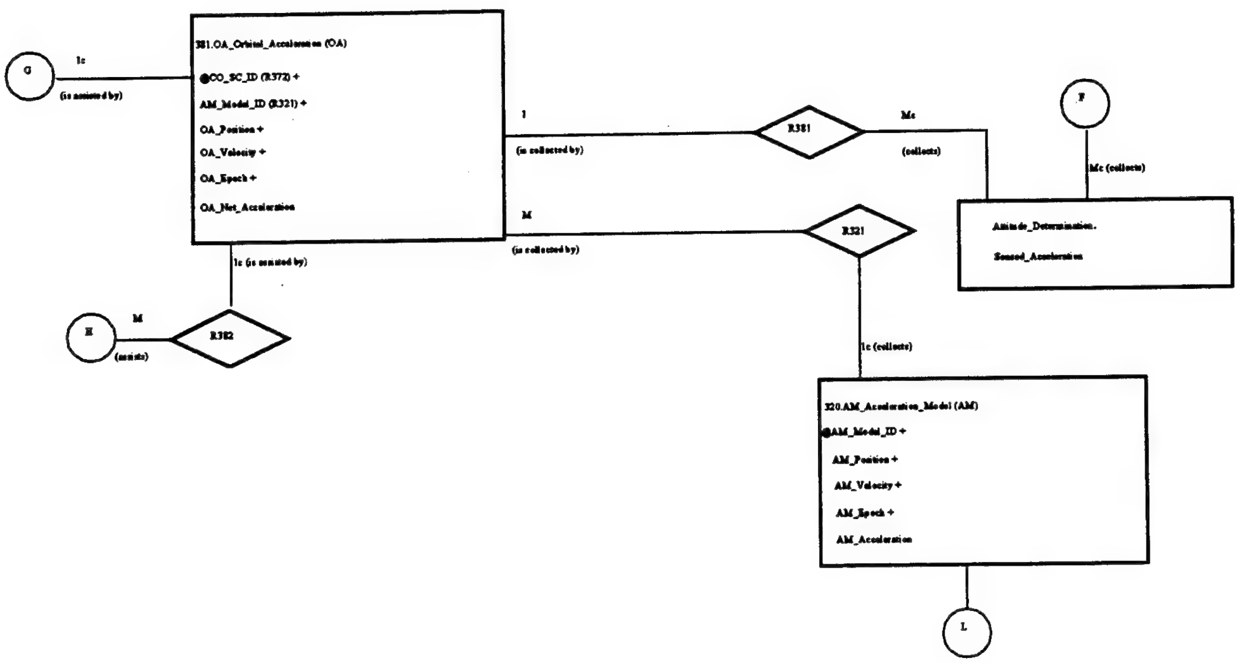
Orbit Determination Information Model



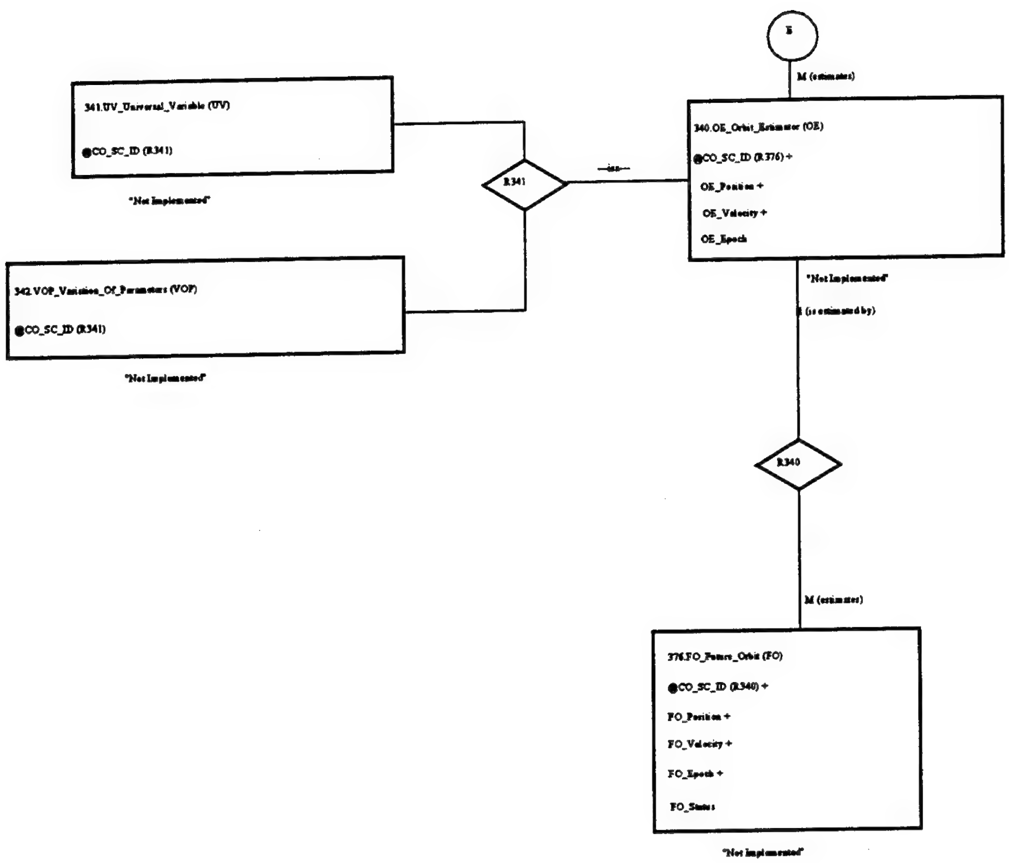
Orbit Determination Information Model (cont'd)



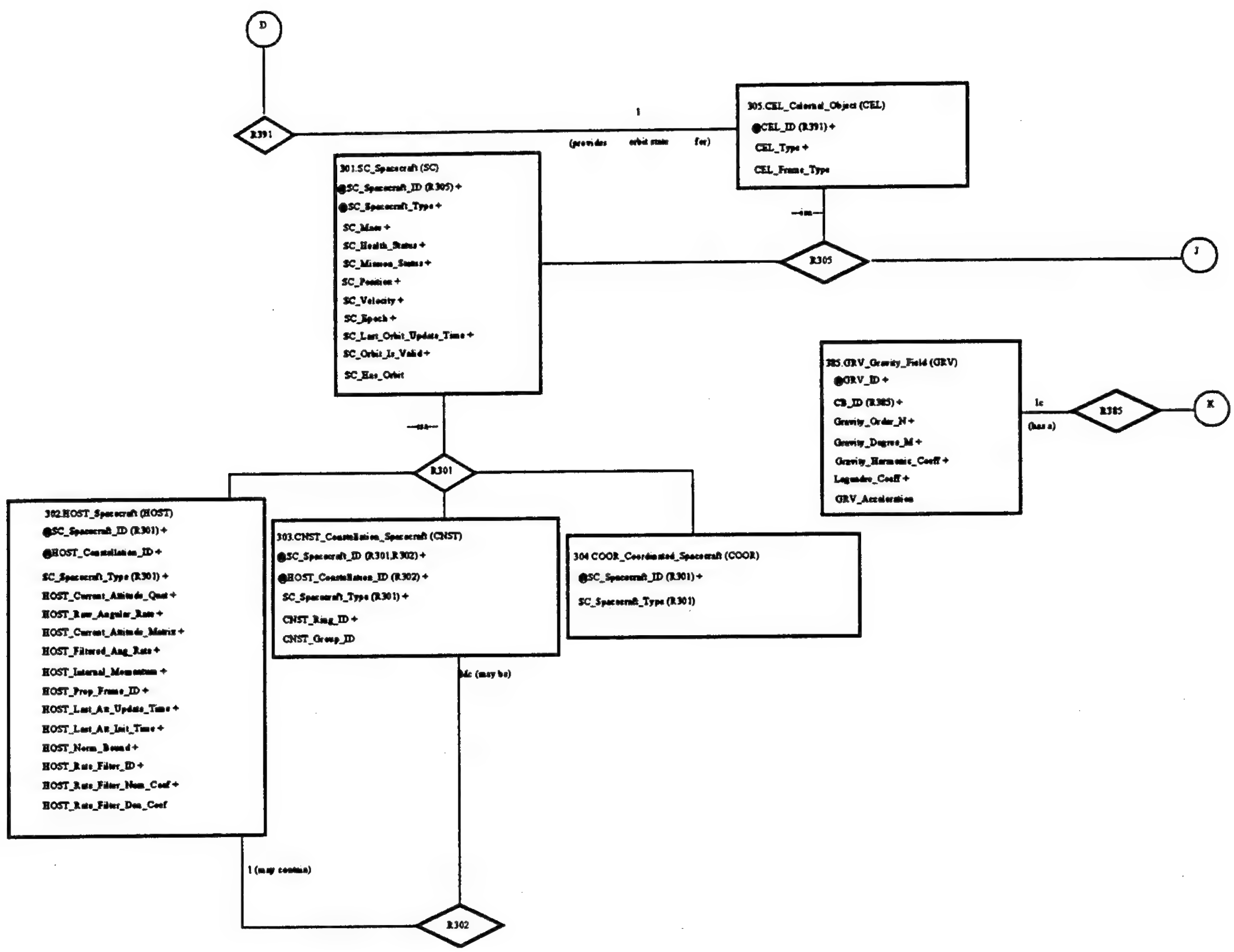
Orbit Determination Information Model (cont'd)



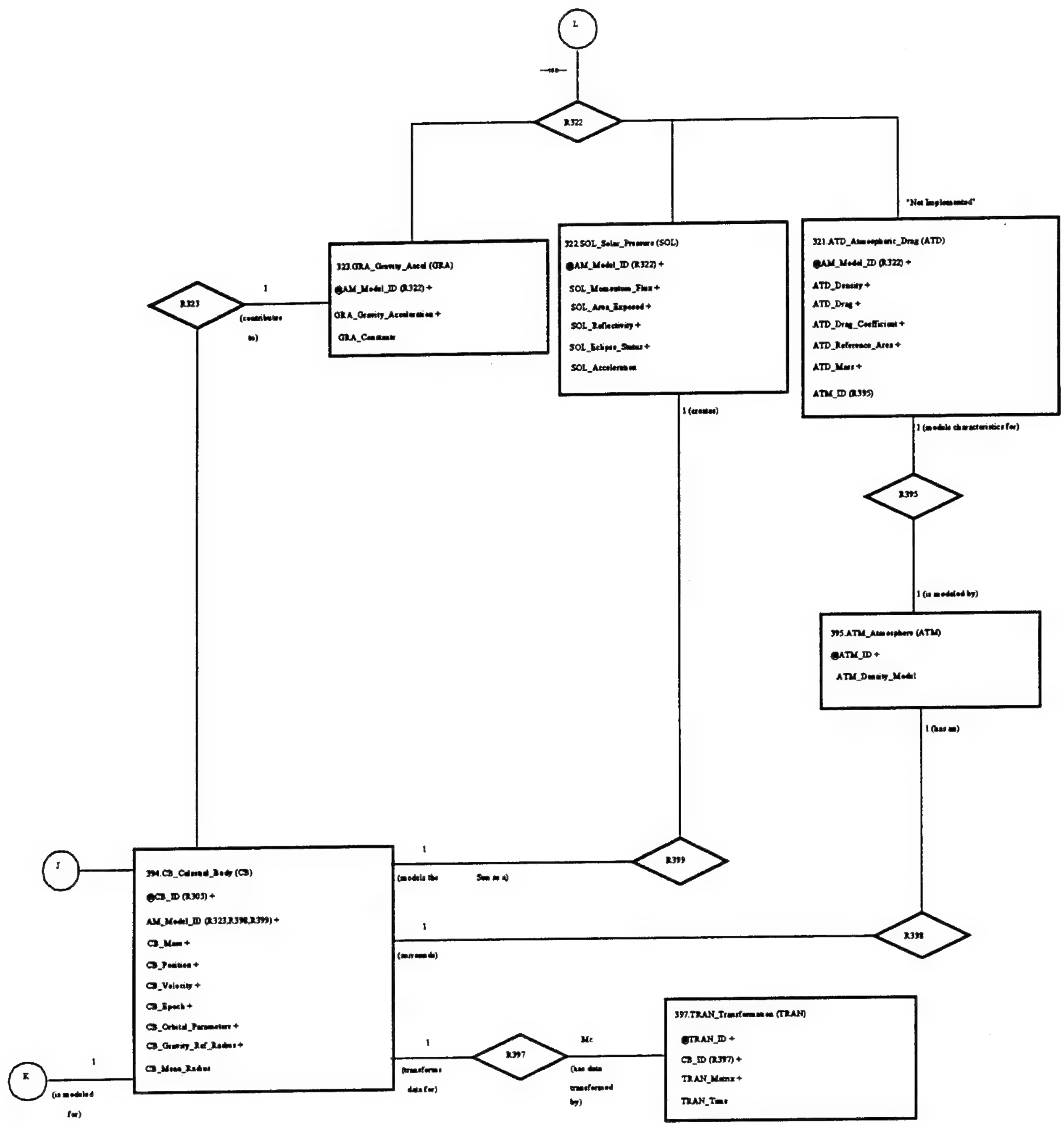
Orbit Determination Information Model (cont'd)



Orbit Determination Information Model (cont'd)



Orbit Determination Information Model (cont'd)



Orbit Determination Information Model (cont'd)

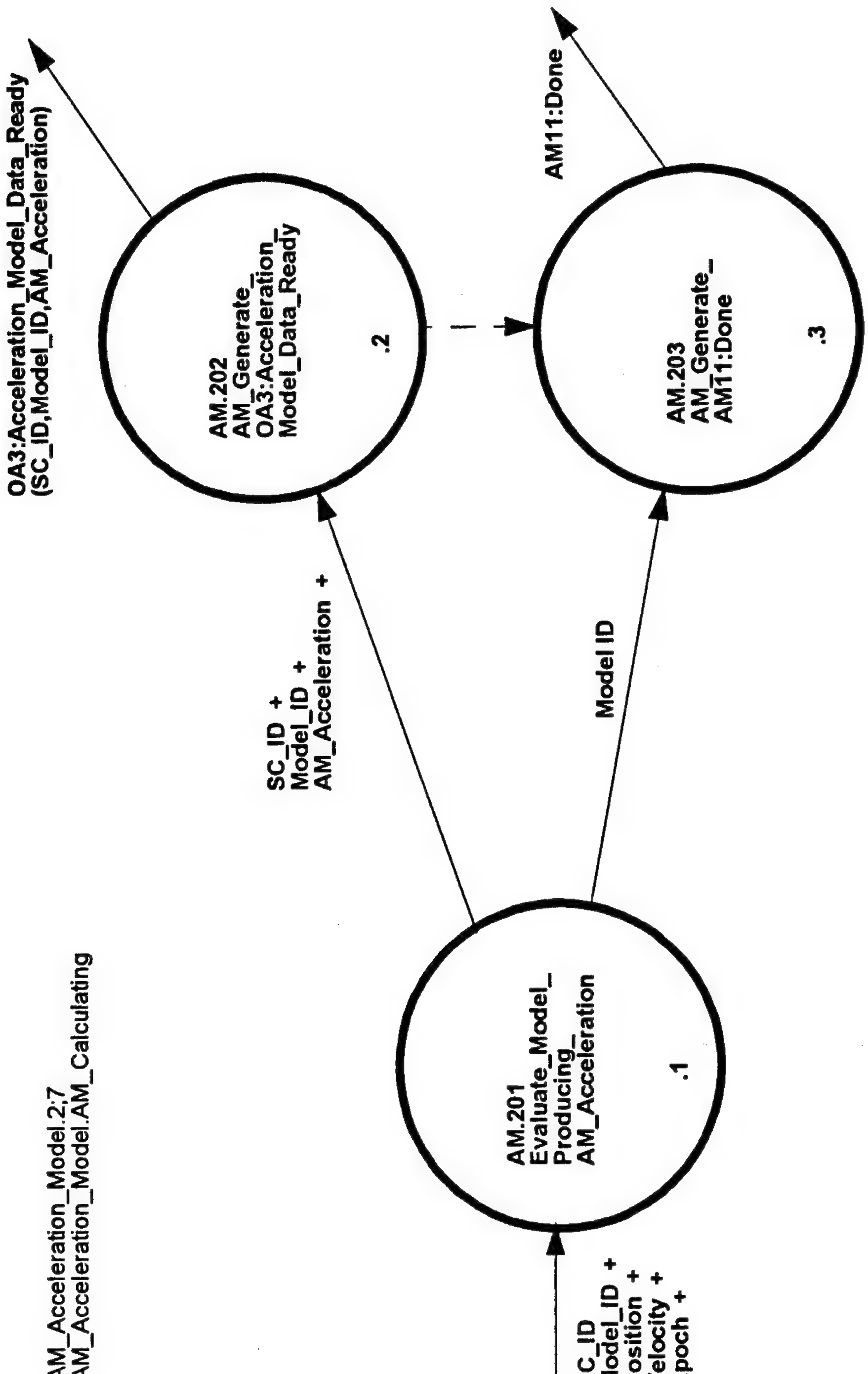
APPENDIX F—Examples of Textual Data

OP_Orbit_Propagator (data flow) =

@CO_SC_ID(R352,R382) +
@OP_Propagator_ID +
OP_Delta_Position +
OP_Velocity +
OP_Epoch +
OP_Acceleration +
OP_Forward

DescriptionType	Object;
Subsystem	Orbit Determination;
KeyLetter	OP;
ObjectNumber	350;
Assigner	FALSE;
Active	TRUE;
Description	This is the single object necessary, from the CO_Current_Orbit objects point of view, to cause an orbit to be stepped forward in time. It is responsible for both forward and real-time propagations and produces changes to the current orbit knowledge of a spacecraft.;

Example of Data Dictionary Entry (DDE)



Example of Data Flow Diagram (DFD)

10:13:01 12 Jan 95 D77D_Flight.Spacecraft_Flight_SW.Orbit_Determination P-Spec AM.2

NAME:
AM.201;4

TITLE:
AM_Evaluate_Model_Producing_AM_Acceleration

INPUT/OUTPUT:
SC_ID : data_in
Model_ID : data_in
Position : data_in
Velocity : data_in
Epoch : data_in
AM_Acceleration : data_out
Model_ID : data_out
SC_ID : data_out

BODY:

Note: At this point a particular model has been matched with a spacecraft and the current spacecraft's ID and orbit are passed along. For some models this is all the external information that is needed, others will need to acquire data from other objects in the orbit determination subsystem and elsewhere.

All Acceleration models used in the system (identified by the enumeration list used, in part, to instantiate the Ada generic package gen_propagation_table) shall be accounted for in this object.

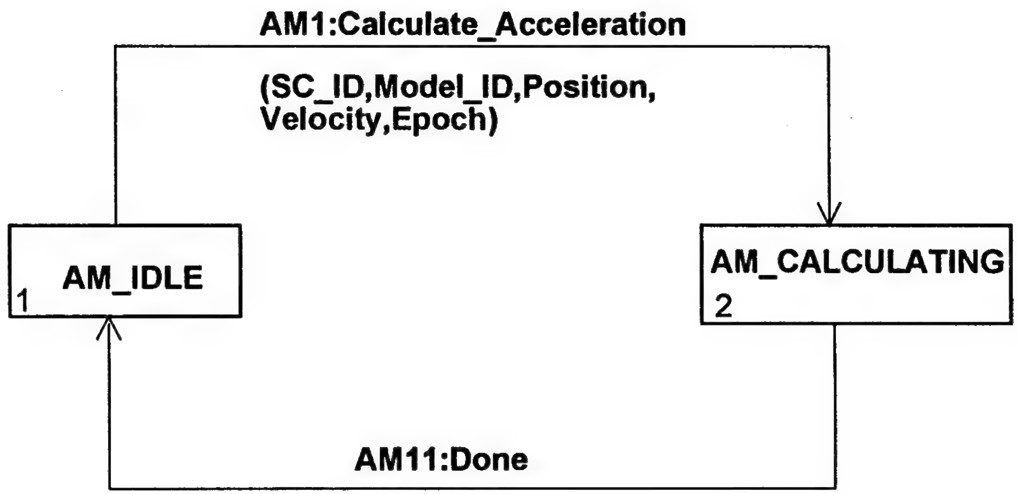
The identified model shall be evaluated and the acceleration vector produced.

```
--invoke the acceleration model identified as Model_ID, passing in the orbit data,
--an acceleration vector is the result
AM_Acceleration := <acceleration vector produced by the model>;
```

Upon return; the acceleration vector shall be expressed in the system's inertial coordinate frame.

Example of Process Specification (P-Spec)

AM_Acceleration_Model.SM;6
AM_Acceleration_Model



1) AM_IDLE

2) AM_CALCULATING AM_Acceleration <-- result of executing algorithm
%generate OA3:Acceleration_Model_Data_Ready (AM_Model_Id, AM_Acceleration)
%generate AM11:Done

Example of State Transition Diagram (STD)

AM_Acceleration_Model.STT;4
AM_Acceleration_Model

States	*Events*		*Actions*
	AM1:Calculate_ Acceleration	AM11:Done	
1. AM_IDLE	2	can't happen	1.Wait for trigger event
2. AM_CALCULATING	can't happen	1	1.Compute acceleration

Example of State Transition Table (STT)

APPENDIX G—Outline for Software Product Development Folder

Software Product Development Folder Outline

The Software Product Development Folder (SPDF) is a development tool used to document requirements, design, informal testing, modification and other supporting information for each software component. A SPDF is maintained by the software engineer responsible for the component. The SPDF provides the input data for the component acceptance review. It contains the following information divided into the indicated sections.

a. Cover Sheet

   This section provides the identification of the software component and contents of the SPDF.

b. Section 1—Requirements

   This section identifies the requirements that have been allocated to the software component and subordinate units. Any assumptions, ambiguities, deferrals, or conflicts concerning the requirements and their effect on the design and development of the component should be stated here. References to other documentation, such as Cadre Teamwork models, may be included.

c. Section 2—Design Description

   This section contains the current description of the design for the software component and subordinate units. It may include references to other documentation, such as Cadre Teamwork models. The design will be captured in the form of Buhr diagrams and Ada PDL (Program Description Language). Throughout the development process this section describes the current working version of the software component; therefore, it must be maintained as changes are made to the design. It also identifies any pertinent design considerations, constraints or limitations.

d. Section 3—Source Code

   This section contains a list of electronic filenames which comprise the software component. The filenames will be unique from all others in the component library. Traceability to design will be shown in this section as well.

e. Section 4—Software Component Test Plan/Test Case Description

   This section contains a description of the component test plan and related test case descriptions. It identifies the component, contains a description of functions to be tested, and test methodology. The test case descriptions summarize software setup, input data, expected output data, test procedures and test driver files used during unit tests.

f. Section 5—Software Component Test Case Results

   This section contains a list of electronic filenames for actual output data files (if generated) during test and test history log that records evidence of test performance. The test history log will contain the component test configuration, testing data, test output, test conductor's name, software versions and a synopsis of significant test results.

g. Section 6—Notes

   This section contains pertinent information dealing with this software component that is not covered in one of the other sections. Examples include, run-time size and speed metrics, walkthrough checklists, and Action Item logs.

h. Section 7—SDP Addendum

Any software component-unique process considerations not discussed in the SDP will be covered in this section.

APPENDIX H—Software Components for GN&C

Attitude Determination Objects/Components

Object ID	Object Name	Description
101	SC_Orientation	Host Spacecraft Attitude and Rate
110	IRU_Sensor	Inertial Reference Unit (Gyro)
111	IRU_Measurement	Raw Measurement from Channel
112	Rate_Integ_IRU_Meas	Rate Integrating Gyro Measurement
113	Rate_IRU_Meas	Rate Gyro Measurement
114	Selected_IRU_Channel	Selects IRU Channels for S/C Axes
115	ACC_Accel_Sensor	Accelerometer
116	Accel_Channel	Raw Accelerometer Channel
117	Selected_Accel_Channel	Selects Accelerometer Channels for S/C Axes
118	Sensed_Acceleration	S/C Acceleration in Body Coordinates
119	ICH_IRU_Channel	Defines Raw IRU Channel
120	Attitude_Sensor	Defines an Attitude Sensor, Common to All Sensors
121	Star_Scanner	Defines a Star Scanner
122	Star_Tracker	Defines a Star Tracker
123	Magnetometer	Defines a Three-Axis Magnetometer
124	Sun_Sensor	Defines a Sun Sensor, Common to Analog and Digital
125	Horizon_Sensor_Assembly	Defines a Horizon Sensor Assembly
126	Analog_Sun_Sensor	Defines an Analog Sun Sensor
127	Digital_Sun_Sensor	Defines a Digital Sun Sensor
128	Scanning_Horizon_Sensor_Assembly	Describes Scanning Horizon Sensor
129	Static_Horizon_Sensor_Assembly	Describes Static Horizon Sensor
140	Modeled_Magnetic_Field	Describes Magnetic Field of Orbited Body
141	Sensed_Magnetic_Field	Describes the Measured Magnetic Field of Orbited Body
142	Sensed_Orbit_Focus	Describes the Calculated Focus of the Orbit
143	Sensed_Sun	Describes the Sensed Sun
150	Initial_Attitude	Initial Attitude for Host Spacecraft
151	Gnd_Relative_Init_Att	Initial Attitude Described Relative to Current Attitude
152	Gnd_Absolute_Init_Att	Initial Attitude Described Absolutely
153	Computed_Init_Attitude	Initial Attitude Computed from Two Independent Sensor Observations
160	SC_Orientation_Delta	Observed Attitude Change over Previous Cycle
161	IRU_Orientation_Delta	Observed Attitude Change from IRU
162	Att_Sensor_Orientation_Delta	Observed Attitude Change from Attitude Sensors
163	Observation_Selector	Selects Attitude Sensors for Observing Attitude Change
169	SC_Meas_Snapshot	Snapshot of Spacecraft States at Measurement Time
170	Attitude_Observation	Observation from Attitude Sensors
171	Scanned_Star	Observation of a Star from a Star Scanner
172	Tracked_Star	Observation of a Star from a Star Tracker
173	Mag_Field_Observation	Observation of Magnetic Field from TAM
174	Sun_Observation	Observation of Sun from Sun Sensor
175	Orbit_Focus_Observation	Observation of Orbited Body from Horizon Sensor
180	Identified_Star	Identification of Observed Star in Star Catalog

Attitude Determination Objects/Components (cont'd)

Object ID	Object Name	Description
181	Star_for_Scanning	Star that has been Selected for Scanning by Star Scanner
182	Star_for_Tracking	Star that has been Selected for Tracking by Star Tracker
183	Catalog_Star	Star that is Described in the Star Catalog
184	Star_Catalog	Collection of Stars with Defined Minimum Separations and Mv Range
185	Selected_Star_Catalog	Star Catalog Currently Selected for Use
190	Attitude_Update_Filter_6	Attitude Updates Produced by 6-State EKF
191	Attitude_Update_Filter_3	Attitude Updates Produced by 3-State EKF
192	AUFP_Att_Updt_Filter_Params	Defines Attitude Filter Parameters
193	Attitude_Update_Filter	Defines an Generic Attitude Estimator; used for analysis only
194	Filter_Obs_Selector	Selects Observations for Attitude Updates

Attitude Control Objects/Components

Object ID	Object Name	Description
200	Reference_Orientation	Describes the Desired Orientation of the Host Spacecraft
203	Nadir_Reference	Describes the Desired Orientation for a Nadir Reference
204	Sun_Reference	Describes the Desired Orientation for a Sun Reference
205	Fixed_Inertial_Reference	Describes the Desired Orientation for a Fixed Reference
206	Slew_Reference	Describes the Desired Orientation for a Slew Maneuver
207	Relative_Slew_Reference	Describes the Desired Orientation for a Relative Slew
208	Absolute_Slew_Reference	Describes the Desired Orientation for an Absolute Slew
209	Earth_Point_Reference	Describes the Desired Orientation to Track a Fixed Earth Point
210	Moving_Inertial_Reference	Describes the Desired Orientation for a Moving Reference
211	LVLH_FrameVector_Reference	Describes Vector in the Local Vertical/Local Horizontal Frame
215	Future_Attitude	Describes the Future Orientation of the Host Spacecraft
216	Future_Nadir_Attitude	Describes the Future Orientation of a Nadir Pointing Spacecraft
217	Future_Earth_Point_Attitude	Describes the Future Orientation of an Earth Tracking S/C
218	Future_Moving_Inertial_Attitude	Describes the Future Orientation of a Spacecraft Tracking a Moving Point
220	Momentum_Exchange_Device	Defines a Momentum Exchange Device (all types)
221	Reaction_Wheel	Defines a Reaction Wheel
222	Bias_Momentum_Wheel	Defines a Bias Momentum Wheel
223	Dual_Gimbal_Mom_Wheel	Defines a Dual-Gimbal Momentum Wheel
224	Control_Moment_Gyro	Defines a Control Moment Gyro
230	Magnetic_Torquer	Defines a Magnetic Torque Rod
240	Gas_Jet	Defines a Gas Jet
241	Gas_Jet_Command	Models Commanding of Gas Jets
250	Spacecraft_Controller	Defines an Attitude Control Law (all types)
251	PID_Att_Controller	Defines a Momentum Exchange Device Control Law
253	Phase_Plane_Att_Controller	Defines a Gas Jet Control Law
254	Phase_Plane	Defines a Phase Plane used for Controlling Gas Jets
255	Linear_Phase_Plane	Defines Linear Phase Plane
256	Box_Phase_Plane	Defines Box Phase Plane
260	Momentum_Controller	Define Controller for Actuator Suite
270	Actuator_Suite	Defines Actuator Suite
271	MED_Suite	Selects Momemtum Exchange Devices for Attitude Control
272	Thruster_Suite	Selects Gas Jets for Firing
273	Mag_Torquer_Suite	Selects Suite of Magnetic Torquers

Orbit Determination Objects/Components

Object ID	Object Name	Description
301	SC_Spacecraft	Defines Generic Spacecraft Characteristics
302	HOST_Spacecraft	Defines Host Spacecraft
303	CNST_Constellation_Spacecraft	Associates Spacecraft with a Constellation of Spacecraft
304	COOR_Coordinated_Spacecraft	Associates Spacecraft
305	CEL_Celestial_Object	Defines Generic Celestial Object (Celestial Body or Spacecraft)
320	AM_Acceleration_Model	Models Linear Acceleration on Defined Spacecraft
321	ATD_Atmospheric_Drag	Models Atmospheric Drag on Defined Spacecraft
322	SOL_Solar_Pressure	Models Solar Pressure on Defined Spacecraft
323	GRV_Gravity_Accel	Models Gravitational Acceleration on Defined Spacecraft
340	OE_Orbit_Estimator	Used to Predict Orbital States based on Known States at Another Time
341	UV_Universal_Variable	One way to Predict Orbital States
342	VOP_Variation_of_Parameters	Another way to Predict Orbital States
350	OP_Orbit_Propagator	Describes an Orbital Propagator (all types)
351	RK_Runge_Kutta	Describes the Runge-Kutta Orbit Propagator
352	ENC_Encke	Describes the Encke Orbit Propagator
353	CWL_Cowell	Describes the Cowell Orbit Propagator
354	AB_Adams_Bashforth	Describes the Adams-Bashforth Orbit Propagator
355	Velocity_Only	Describes the Velocity-Only Orbit Propagator
356	VCA_Vel_Const_Accel	Defines Constant Acceleration Orbit Propagator
360	OS_Orbit_Sensor	Defines an Orbit Sensor (all types)
361	GPS_Sensor	Defines a Global Positioning System Sensor
362	TONS_Sensor	Defines a TDRS Onboard Navigation System Sensor
363	CLR_Sensor	Defines a Cross-Link Ranging Navigation Sensor
364	COMM_Sensor	Defines a Communicated Navigation Sensor
365	KP_Known_Point	Defines a Known Point (Waypoint) Navigation Sensor
370	FIL_Filter	Generates Orbit Updates using Extended Kalman Filter
371	OU_Orbit_Update	Describes an Update to the Orbit of a Spacecraft (from all sources)
373	PT_Propagation_Table	Defines Propagation Methods for a Spacecraft
374	CO_Current_Orbit	Describes the Current Orbits of All Defined Spacecraft
375	UT_Update_Table	Defines Update Methods for a Spacecraft
376	FO_Future_Orbit	Describes the Future (Predicted) Orbit for a Spacecraft
377	EPH_Ephemeris	Describes the Orbit of a Spacecraft Based on an Ephemeris Table
378	COEF_Coefficient_Set	Defines the Curve Fitting Coefficients for an Ephemeris Table
379	ET_Ephemeris_Table	Defines an Ephemeris Table for a Spacecraft
381	OA_Orbital_Acceleration	Describes the Linear Acceleration of a Spacecraft
385	GRV_Gravity_Field	Defines the Gravity Field of a Celestial Body
394	CB_Celestial_Body	Describes a Celestial Body (all types)
395	ATM_Atmosphere	Define Atmosphere for Celestial Body
397	TRAN_Transformation	Define Frame Transformation

APPENDIX I—Preliminary Software Components for COMM

Communications Subsystem Objects/Components

Object ID	Object Name	Description
801	Antenna	Defines Communications Antenna
802	Fixed_Antenna	Defines Fixed Antenna
803	Gimballed_Antenna	Defines Gimballed Antenna
805	Autotrack_Receiver	Defines Auto-track Receiver
806	Monopulse_Feed	Defines Monopulse Scan Mode for Auto-tracking
807	Conical_Scan	Defines Conic Scan Mode for Auto-tracking
808	Step_Track	Defines Step Scan Mode for Auto-tracking
809	Acquisition_Sequencer	Retains Link Acquisition Schedule
810	Comm_Node	Defines Generic Communications Node
811	Space_Node	Defines Space-Based Communications Node
813	Ground_Node	Defines Ground-Based Communications Node
820	Comm_Link	Monitors and Coordinates Communications Link
860	Channel	Defines Channel for Communications Link
861	Open_Channel	Identifies Open Channel
862	Closed_Channel	Identifies Closed Channel
865	Transponder	Defines Transponder
866	Receiver	Defines Receiver
867	Transmitter	Defines Transmitter
890	Motor	Defines Generic Motor
891	Stepper_Motor	Defines Stepper Motor
892	DC_Motor	Defines Direct Current Motor
893	Brushed_Motor	Defines Brushed Direct Current Motor
894	Brushless_Motor	Defines Brushless Direct Current Motor

APPENDIX J—Preliminary Software Components for EPS

Electrical Power Subsystem Objects/Components

Object ID	Object Name	Description
600	BAT_Battery	Defines Secondary Power Source
601	BHM_Battery_Health_Monitor	Provides Battery Health and Status Monitor
602	BCH_Battery_Calibration_History	Maintains Battery Calibration History for Life-Cycle Estimation
605	BCT_Battery_Capacity_Tester	On-line Test for Battery Capacity Level
606	BPT_Battery_Performance_Tester	On-line Test for Battery Performance Level
609	CCC_Constant_Current_Charger	Defines Constant Current Battery Charger Profile
610	BCC_Battery_Charge_Controller	Defines Battery Charge Controller
611	BSM_Battery_Charge_State_Monitor	Monitors Battery Charge to Determine End Of Charge State
612	AHC_Amp_Hour_Charger	Defines Amp Hour Battery Charger Algorithm
613	DLC_Dual_Level_Charger	Defines Dual Level Battery Charger Algorithm
614	VLC_Voltage_Limited_Charger	Defines Voltage Limited Battery Charger Algorithm
615	VTC_VT_Curve	Defines Voltage vs Temperature Curve for Battery Charging
616	TLC_Taper_Charger	Defines Taper Battery Charge Algorithm
617	RLB_Reconditioning_Load_Bank	Defines Reconditioning Load Bank for Quick Discharge
618	RBC_Reconditioning_Battery_Charger	Defines Reconditioning Battery Charger
619	REC_Reconditioning_Controller	Defines Reconditioning Controller
620	SA_Solar_Array	Defines Array of Solar Collectors for Primary Power Source
621	SHM_SA_Health_Monitor	Defines Solar Array Health Monitor
623	CAPC_Current_Angle_Power_Curve	Defines Solar Array Current vs Voltage Curve
630	SAC_Solar_Array_Controller	Controls Position of Solar Array
631	SCON_SA_Motor_Driver	Defines Single Degree of Freedom Driver for Solar Array
632	SPOS_Sun_Position	Defines Positioning for Solar Tracking
633	DRG_Drag_Optimizer	Algorithm which Optimizes Solar Array to Minimize Drag
640	PRU_Power_Regulator_Unit	Defines Power Regulator
641	PBM_Power_Bus_Monitor	Monitors Bus Power and Determines Relay States
644	AHI_Amp_Hour_Integrator	Monitors Consumed Power to Aid in Battery Charging
660	IND_Indicator	Defines Generic Indicator to Measure a Single Property
661	CIND_Current_Indicator	Defines Current Indicator
662	VIND_Voltage_Indicator	Defines Voltage Indicator
663	TIND_Temperature_Indicator	Defines Temperature Indicator
664	PIND_Pressure_Indicator	Defines Pressure Indicator
671	PPT_Peak_Power_Tracker	Defines Peak Power Method for Solar Power Control
672	DET_Direct_Energy_Transfer	Defines Direct Power Transfer for Dissipation of Excess Power
673	SHUN_Shunt_Regulator	Defines Shunt Regulator
676	REL_Relay	Defines Generic Power Relay

APPENDIX K—Software Component Evaluation Tables for GN&C

Attitude Determination Component Evaluation Table

(Object) Component Name	ID	Component Verification Criteria Assessment Values							(Priority) Total
		A	B	C	D	E	F	G	
ACC_Accel_Sensor	115	0	2	2	2	2	2	0	10
Accel_Channel	116	0	2	2	2	2	2	0	10
Analog_Sun_Sensor	126	0	2	2	2	2	2	0	10
Att_Sensor_Orientation_Delta	162	0	2	2	2	2	2	0	10
Attitude_Observation	170	2	2	2	2	2	2	2	14
Attitude_Sensor	120	2	2	2	2	2	2	1	13
Attitude_Update_Filter	193	0	0	0	0	0	0	0	0
Attitude_Update_Filter_3	191	2	2	2	2	2	2	2	14
Attitude_Update_Filter_6	190	2	2	2	2	2	2	2	14
AUFP_Att_Updt_Filter_Params	192	1	2	2	2	2	2	1	12
Catalog_Star	183	1	2	2	2	2	2	1	12
Computed_Initial_Attitude	153	0	2	2	2	2	2	0	10
Digital_Sun_Sensor	127	0	2	2	2	2	2	0	10
Filter_Obs_Selector	194	2	2	2	2	2	2	1	13
Gnd_Absolute_Init_Att	152	0	2	2	2	2	2	0	10
Gnd_Relative_Init_Att	151	0	2	2	2	2	2	0	10
Horizon_Sensor_Assembly	125	0	0	0	0	0	0	0	0
ICH_IRU_Channel	119	2	2	2	2	2	2	1	13
Identified_Star	180	1	2	2	2	2	2	1	12
Initial_Attitude	150	0	0	0	0	0	0	0	0
IRU_Measurement	111	1	2	2	2	2	2	1	12
IRU_Orientation_Delta	161	0	0	0	0	0	0	0	0
IRU_Sensor	110	1	2	2	2	2	2	1	12
Mag_Field_Observation	173	0	2	2	2	2	2	0	10
Sensed_Magnetic_Field	141	0	2	2	2	2	2	0	10
Magnetometer	123	0	2	2	2	2	2	0	10
Modeled_Magnetic_Field	140	0	2	2	2	2	2	0	10
Observation_Selector	163	0	2	2	2	2	2	0	10
Sensed_Orbit_Focus	142	0	2	2	2	2	2	0	10
Orbit_Focus_Observation	175	0	2	2	2	2	2	0	10
Rate_Integ_IRU_Meas	112	0	2	2	2	2	2	0	10
Rate_IRU_Meas	113	0	2	2	2	2	2	0	10
SC_Meas_Snapshot	169	2	2	2	2	2	2	2	14

Attitude Determination Component Evaluation Table (cont'd)

(Object) Component Name	ID	Component Verification Criteria Assessment Values							(Priority) Total
		A	B	C	D	E	F	G	
SC_Orientation	101	2	2	2	2	2	2	2	14
SC_Orientation_Delta	160	0	0	0	0	0	0	0	0
Scanned_Star	171	0	1	1	1	0	2	0	5
Scanning_Horizon_Sensor_Assembly	128	0	2	2	2	2	2	0	10
Selected_Accel_Channel	117	0	2	2	2	2	2	0	10
Selected_IRU_Channel	114	1	2	1	2	1	2	1	10
Selected_Star_Catalog	185	1	2	2	2	2	2	1	12
Sensed_Acceleration	118	0	2	2	2	2	2	0	10
Star_Catalog	184	1	2	2	2	2	2	1	12
Star_for_Scanning	181	0	0	0	0	0	0	0	0
Star_for_Tracking	182	0	0	0	0	0	0	0	0
Star_Scanner	121	0	1	1	1	0	2	0	5
Star_Tracker	122	2	1	2	1	2	2	1	11
Staring_Horizon_Sensor_Assembly	129	0	2	2	2	2	2	0	10
Sensed_Sun	143	0	2	2	2	2	2	0	10
Sun_Sensor	124	0	2	2	2	2	2	0	10
Sun_Observation	174	0	2	2	2	2	2	0	10
Tracked_Star	172	1	2	2	2	2	2	2	13

Attitude Control Component Evaluation Table

(Object) Component Name	ID	Component Verification Criteria Assessment Values A	B	C	D	E	F	G	(Priority) Total
Absolute_Slew_Reference	208	2	2	2	2	2	2	2	14
Actuator_Suite	270	2	2	2	2	2	2	1	13
Spacecraft_Controller	250	0	0	0	0	0	0	0	0
Bias_Momentum_Wheel	222	0	1	0	1	1	2	0	6
Box_Phase_Plane	256	2	2	2	2	2	2	1	13
Control_Moment_Gyro	224	0	1	0	1	1	2	0	5
Dual_Gimbal_Mom_Wheel	223	0	1	0	1	1	2	0	5
Earth_Point_Reference	209	0	1	2	1	2	2	0	8
Fixed_Inertial_Reference	205	2	2	2	2	2	2	0	12
Future_Attitude	215	0	0	0	0	0	0	0	0
Future_Earth_Point_Attitude	217	0	0	0	0	0	0	0	0
Future_Moving_Inertial_Attitude	218	0	0	0	0	0	0	0	0
Future_Nadir_Attitude	216	0	0	0	0	0	0	0	0
Gas_Jet	240	2	2	2	2	2	2	0	12
Gas_Jet_Command	241	2	2	2	2	2	2	0	12
Linear_Phase_Plane	255	2	2	2	2	2	2	1	13
LVLH_Frame_Vector_Reference	211	2	2	2	2	2	2	1	13
Mag_Torquer_Suite	273	1	2	2	2	2	2	1	12
Magnetic_Torquer	230	1	2	2	2	2	2	0	11
MED_Suite	271	2	2	2	2	2	2	1	13
Momentum_Controller	260	2	2	2	2	2	2	2	14
Momentum_Exchange_Device	220	2	2	2	2	2	2	1	13
Moving_Inertial_Reference	210	2	2	2	2	2	2	1	13
Nadir_Reference	203	2	2	2	2	2	2	2	14
Phase_Plane	254	0	0	0	0	0	0	0	0
Phase_Plane_Att_Controller	253	2	2	2	2	2	2	2	14
PID_Att_Controller	251	2	2	2	2	2	2	2	14
Reaction_Wheel	221	2	2	2	2	2	2	2	14
Reference_Orientation	200	2	2	2	2	2	2	2	14
Relative_Slew_Reference	207	2	2	2	2	2	2	2	14
Slew_Reference	206	0	0	0	0	0	0	0	0
Sun_Reference	204	2	2	2	2	2	2	2	14
Thruster_Suite	272	2	2	2	2	2	2	2	14

Orbit Determination Component Evaluation Table

(Object) Component Name	ID	Component Verification Criteria Assessment Values							(Priority) Total
		A	B	C	D	E	F	G	
AB_Adams_Bashforth	354	2	1	1	2	2	1	2	11
ATD_Atmospheric_Drag	321	1	1	1	1	1	1	2	8
AM_Acceleration_Model	320	1	1	2	2	2	2	1	11
ATM_Atmosphere	395	1	1	1	1	1	1	1	7
CB_Celestial_Body	394	1	0	1	0	1	2	1	6
CEL_Celestial_Object	305	0	0	1	0	1	2	0	4
CLR_Sensor	363	0	1	1	1	1	1	1	6
CNST_Constellation_Spacecraft	303	0	1	2	1	2	2	1	9
COEF_Coefficient_Set	378	0	0	1	0	1	2	0	4
CO_Current_Orbit	374	2	1	2	2	2	2	1	12
COMM_Sensor	364	1	1	1	1	1	1	1	7
COOR_Coordinated_Spacecraft	304	0	1	2	1	2	1	1	8
CWL_Cowell	353	1	1	1	1	1	0	2	7
ENC_Encke	352	1	1	1	1	1	0	2	7
EPH_Ephemeris	377	2	1	2	2	2	1	1	11
ET_Ephemeris_Table	379	1	1	2	1	2	1	1	9
FIL_Filter	370	2	1	2	1	2	0	2	10
FO_Future_Orbit	376	0	1	2	1	2	1	1	8
GPS_Sensor	361	0	1	2	1	2	1	1	8
GRA_Gravity_Accel	323	2	1	2	1	2	2	1	11
GRV_Gravity_Field	385	1	1	1	1	1	1	2	8
HOST_Spacecraft	302	1	1	2	2	2	2	1	11
KP_Known_Point	365	0	1	1	1	1	1	1	6
OA_Orbital_Acceleration	381	1	1	2	2	2	2	1	11
OE_Orbit_Estimator	340	0	1	1	1	1	2	1	7
OP_Orbit_Propagator	350	2	1	2	2	2	2	1	12
OS_Orbit_Sensor	360	1	1	2	2	2	2	1	11
OU_Orbit_Update	371	0	1	2	1	2	2	1	9
PT_Propagation_Table	373	1	1	1	1	1	1	1	7
RK_Runga_Kutta	351	2	1	2	2	2	1	2	12
SC_Spacecraft	301	2	1	2	1	2	2	1	11
SOL_Solar_Pressure	322	1	1	2	1	2	1	2	10
TONS_Sensor	362	0	0	1	0	1	1	2	5

Orbit Determination Component Evaluation Table (cont'd)

(Object) Component Name	ID	Component Verification Criteria Assessment Values A	B	C	D	E	F	G	(Priority) Total
TRAN_Transformation	397	0	2	2	2	2	2	2	12
UT_Update_Table	375	1	1	2	1	2	2	1	10
UV_Universal_Variable	341	0	1	1	1	1	1	1	6
VCA_Vel_Const_Accel	356	2	1	1	2	1	1	0	8
Velocity_Only	355	2	1	1	2	1	1	0	8
VOP_Variation_Of_Parameters	342	0	0	1	1	1	1	1	5

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